Effects of Disturbance on Microbial Communities

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This research addresses the Astrobiology objective regarding ecosystem responses to disturbance. A result of both absolute species numbers in any ecosystem and interactions among members of the community, functional biodiversity plays a pivotal role in the resilience of ecosystems to disturbance and environmental change. Ecosystem reliability can increase when the number of species per functional group increases, thus illustrating the value of functional redundancy or similarity in an ecosystem. On the other hand, gains or losses of species that perform different functions can cause ecosystem processes to be significantly altered. Thus, a controversial aspect of functional diversity is whether species exhibiting similar function are actually redundant, and thus expendable.

This research targets microbes, and a common view is that the potential for redundancy or similarity among microbial species is high. The focus is on one pivotal mutualistic interaction, the ectomycorrhizal (EM) symbiosis, a plant/fungal interaction that controls both carbon and nitrogen cycles in forest ecosystems. This research has two steps: first, to assess changes in the EM community in response to disturbance; and second, to determine if there are functional changes in the ecosystem that result from any changes.

Artificial Defoliation, a manuscript in press at Oecologia, describes the first study of the effects of altered carbon available to roots in systems comprising more than a single tree species. Results indicated no significant effect on either EM colonization or species richness. However, the relative abundance of EM of the two tree species shifted from a ratio of approximately 6:1 without treatment (lodgepole EM:spruce EM), to a near 1:1 ratio after treatment. In addition, EM species composition changed significantly after defoliation. Species of EM fungi associating with both lodgepole pine and Engelmann spruce were affected, indicating that alteration of the photosynthetic capacity of one species can affect mycorrhizal associations of neighboring nondefoliated trees. Finally, although some fungal species may exhibit consistent specificity patterns (for example, *Suillus tomentosus* to *P. contorta*), other fungal species shift host preference in response to the change in source of fixed carbon induced by defoliation.

A study made of the effects of litter addition on a stand of pure lodgepole pine, *P. contorta*, is complete. Molecular analyses indicate that litter addition significantly increases EM infection levels in the topsoil layer, directly adjacent to the added litter. No change is seen with perlite addition. Thus, this response is due solely to nutrient changes imposed by litter. The molecular analyses also indicate that the EM community is altered significantly by litter addition. Species dominant in controls may be lost in response following treatment, and some species increase only in response to litter—not to perlite—further illustrating the role of changes in nutrient status.

Results of molecular analyses of the effects of litter removal on a mixed lodgepole pine/ Englemann spruce (*P. engelmannii*) indicate that litter removal significantly decreased EM fungal species richness, from 3.0 to 1.5 species/core; as expected from previous studies that indicate that increased nitrogen in litter can inhibit EM infection, litter removal induced a significant increase in EM infection, from a mean of 228 EM/core in controls to 326 in treatments; and furthermore, although many basidiomycete fungal species are common to both treatments and controls, the ratio of basidiomycetes to ascomycetes changed significantly in response to litter removal, from a ratio of 12:1 of basidiomycete to ascomycete EM to a ratio of 3:1.

Together, these results indicate that these disturbances can cause changes in the EM fungal community. Because different species may perform different functions, these results indicate that it is now necessary to assess changes to pivotal ecosystem functions. Thus, the next step of this study will be to perform assessments of changes in enzyme systems that are responsible for controlling both nitrogen and carbon cycles in forest ecosystems.

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Structure and Functions of Protocells

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This research studies the origin of cellular functions, with a long-term objective to explain how protocells performed functions essential for their survival and evolution utilizing only molecules that may have been available in the protobiological milieu. Simple models of several protocellular functions have been developed, and computer simulations have been carried out using molecular dynamics (MD) computer simulations. In MD simulations, Newton's equations of motion are solved for all the atoms in the system under study, providing a complete time history of the system. Properties of interest are computed from the trajectory using classical statistical mechanics.

Probably the first cell-like structures were vesicles—closed, spheroidal assemblies of organic material enclosing an aqueous medium. The walls of vesicles are built of amphiphilic molecules that have water-soluble (hydrophilic) and water-insoluble (hydrophobic) groups at opposite ends. These molecules are arranged in bilayers such that the hydrophilic head groups point toward water and the hydrophobic tails form the interior of the bilayer. In this respect, vesicle walls resemble modern cell membranes. Under proper conditions, vesicles form spontaneously from an aqueous solution of amphiphiles. Vesicles became the precursors to true cells—protocells—by acquiring the capabilities needed to survive and reproduce. Protocells had to transport ions and organic matter from the environment across their walls, capture and utilize energy, and synthesize the molecules necessary for self-maintenance and growth. The identity of molecules that performed these functions is open to debate. Because most metabolic functions in modern organisms are carried out by proteins, the most parsimonious assumption is that their protobiological precursors were peptides. Their protocellular potential is illuminated by the fact that a wide range of simple, naturally occurring or synthetic peptides can spontaneously insert into membranes and assemble into channels capable of transporting material across cell walls.

The stability of monomers and dimers of a peptide consisting of leucine (L) and serine (S) in a heptad repeat arrangement of $(LSLLLSL)_3$ has been investigated in a membrane-like system consisting of an octane layer between two water layers. Both the transmembrane and parallel, in-plane orientations of the monomer correspond to stable states, with the parallel orientation being more stable. However, conversion between the two requires crossing a